AMENDED PAGE 1

Patent Application of

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for

USE OF APPLIED FORCE TO IMPROVE MEMS SWITCH PERFORMANCE

CROSS-REFERENCE TO RELATED APPLICATION

This application is a divisional of Application Serial No. 09/834,744, which is based on and claims priority from Provisional application 60/250,081 filed November 29, 2000, both of which are incorporated herein by reference.

FIELD OF THE INVENTION

This invention relates generally to microelectromechanical structures (MEMS). More particularly, it relates to a clamping mechanism for MEMS apparatus.

BACKGROUND OF THE INVENTION

MEMS free-space optical switches can be categorized into two major branches: the planar matrix (2-dimensional) approach, and the beam-steering (3-dimensional) approach. The 2D approach typically involves mirrors that move between on and off position. The angular accuracy at the on position is extremely critical as it affects the alignment of the mirror and optical loss of the switch.

Using <110> silicon with anisotropic etchants, one can form trenches with 90-degree sidewalls. If one bonds this wafer to another wafer that has free rotating mirrors, the sidewall can serve as a reference stopping plane to fix the up- mirrors in a vertical position. In addition, the sidewall may also serve as an electrode for electrostatically clamping the mirror in the vertical position.

One type of optical switch employs microelectromechanically-actuated mirrors. Fig. 1 depicts one type of MEMS actuated

switch **100** that is made using 2 substrates. A top chip **101** containing a sidewall for receiving a movable mirror **111** is bonded to a bottom chip **102** containing a base **103**. There are a few complications associated with the two-wafer approach. The attachment process requires a very high accuracy aligner-bonder. Moreover, the two-chip process places certain geometrical constraints that limit the minimum geometry of the trenches and mirrors. Furthermore, the complexity of the fabrication and alignment process can increase cost and reduce yield. In addition, stiction or squeeze-film damping between the movable mirror **111** and the base **103** may adversely affect the performance of the switch **100**.

Therefore, there is a need in the art for a low-cost, high-yield, high performance, reliable, scalable switch and a process of fabricating same.

SUMMARY OF THE INVENTION

The disadvantages associated with the prior art may be overcome by a method for operating a MEMS device having a flap that is movable with respect to a base. The method includes applying a force to the flap to move the flap at least partially out of contact with an underlying base. Means for applying such a biasing force may be incorporated into a microelectromechanical (MEMS) apparatus having a base and a flap with a bottom portion coupled to the base so that the flap may move out of the plane of the base between first and second angular orientations. An array of one or more of such structures may be used to form an optical switch. The base may have an opening with largely vertical sidewalls containing one or more electrodes. The sidewalls contact a portion of the flap when the flap is in the second angular orientation. The electrodes may be electrically isolated from the base. The flap may include a magnetic material so that the flap moves in response to an external magnetic field. A voltage source may be coupled between the flap and the sidewall electrode to apply an electrostatic force between the sidewall electrode and the flap such that the flap assumes the angular orientation of the sidewall. The electrostatic force may be sufficient to prevent the flap from changing position in the presence of an applied magnetic field. The apparatus may further include an electrode on the base and a voltage